Charm production measurements in the dielectron channel with ALICE

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on behalf of the ALICE Collaboration

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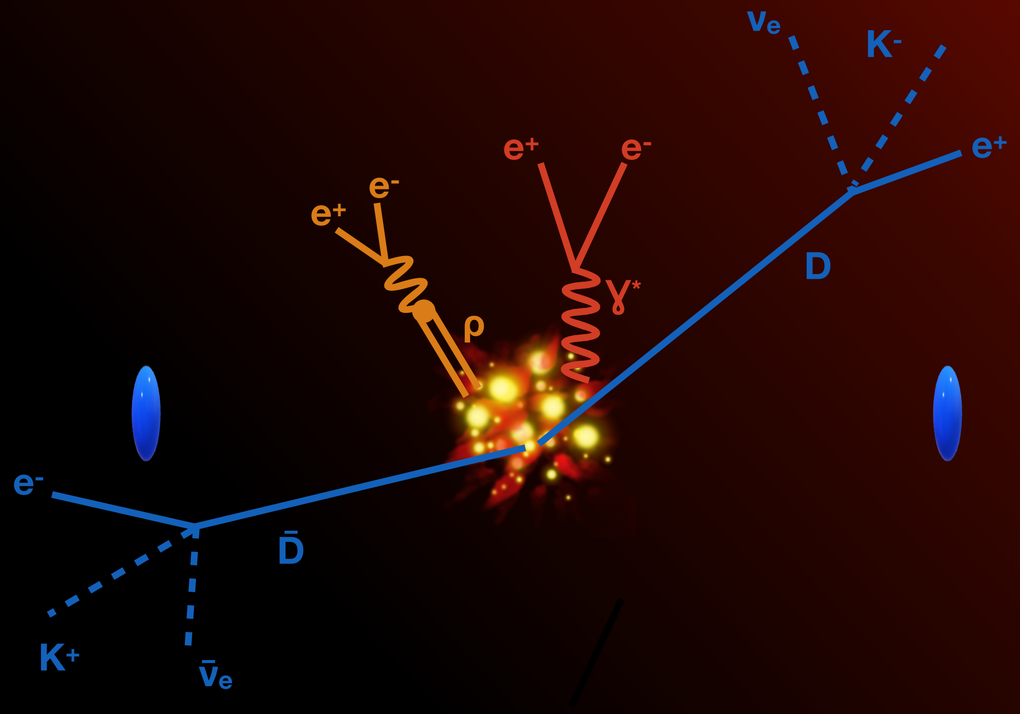
3.6.2021

Motivation

Various sources produce correlated electron-positron pairs:

- Pseudoscalar and vector mesons (π, η, ρ, ω, ϕ, J/ψ) via direct (e^+e^-) or Dalitz (X e^+e^-) decays
- Internal conversion of direct photons
- Semi-leptonic decays of open heavy-flavour (HF) hadrons (e.g. $c\bar{c} \rightarrow D\bar{D} \rightarrow XY\ e^+e^-$)

  ⇨ Sensitive to correlation and soft production of charm-quark pair



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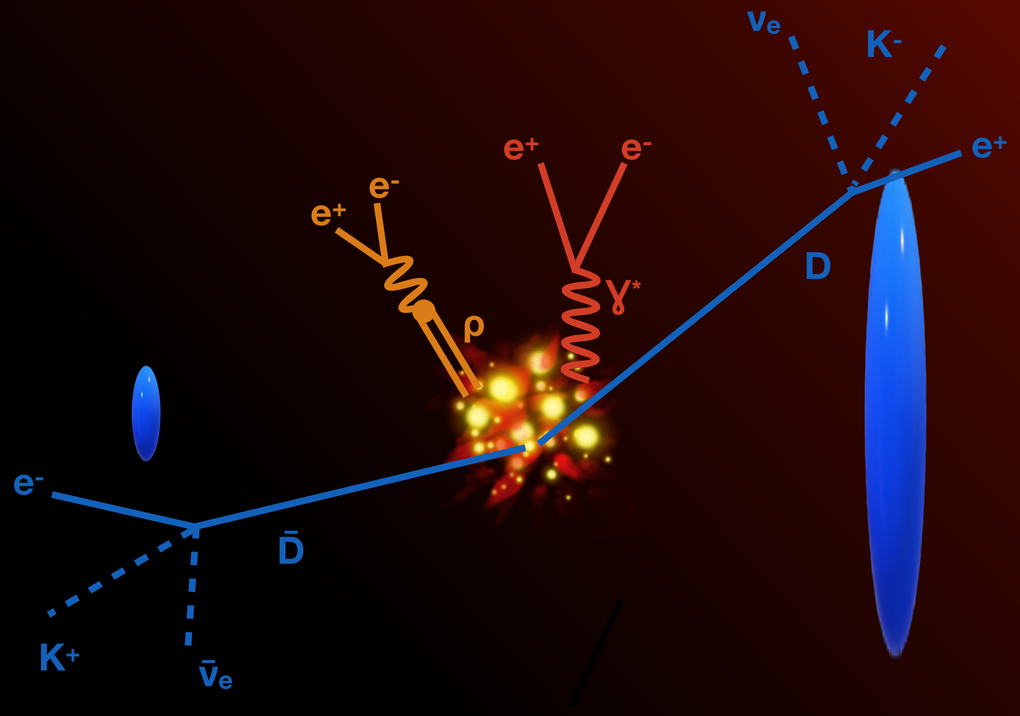
In pA:

- Modification of production cross section of charm quarks via cold nuclear matter effects (e.g. shadowing)
- Additional contribution from a possible hot medium in small systems (hadron gas or quark-gluon plasma)



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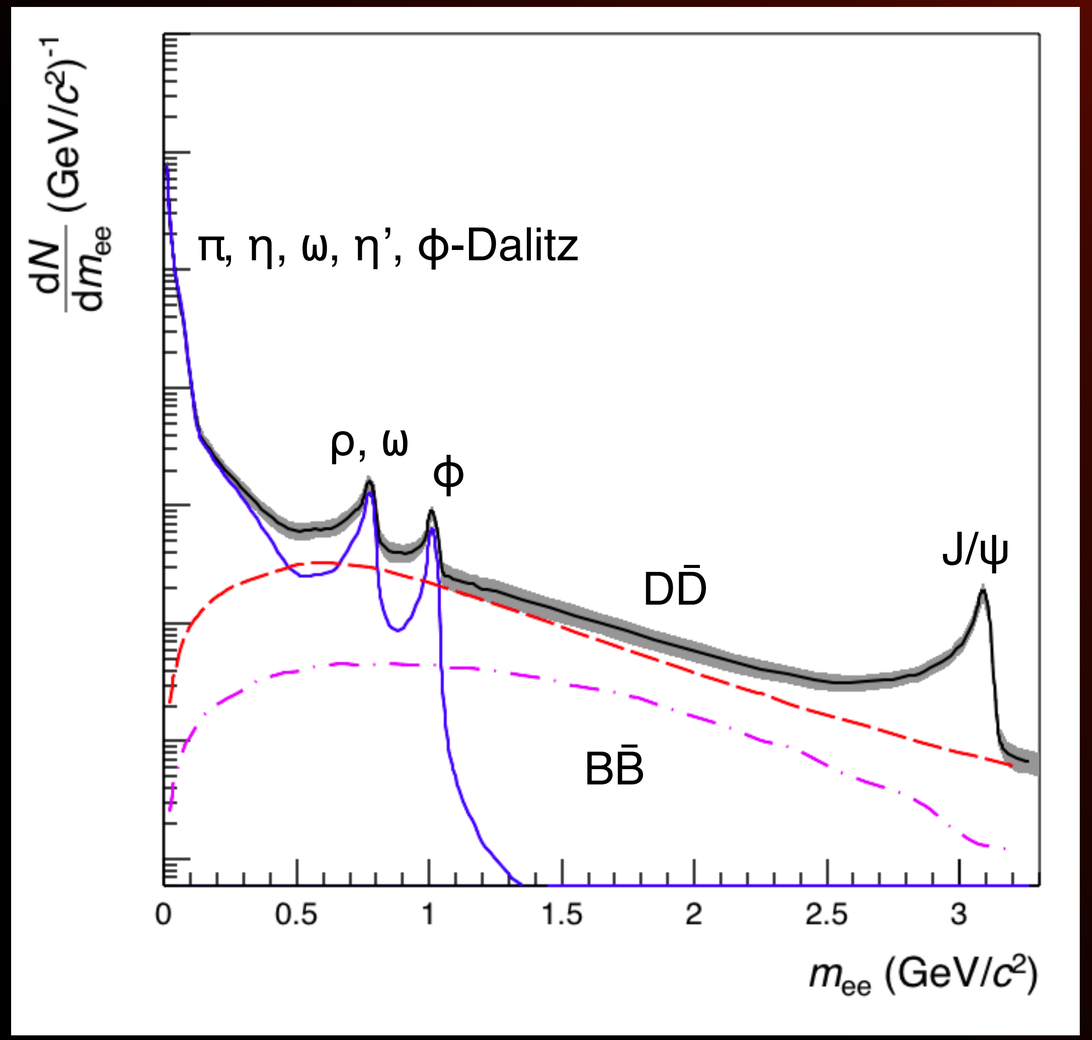

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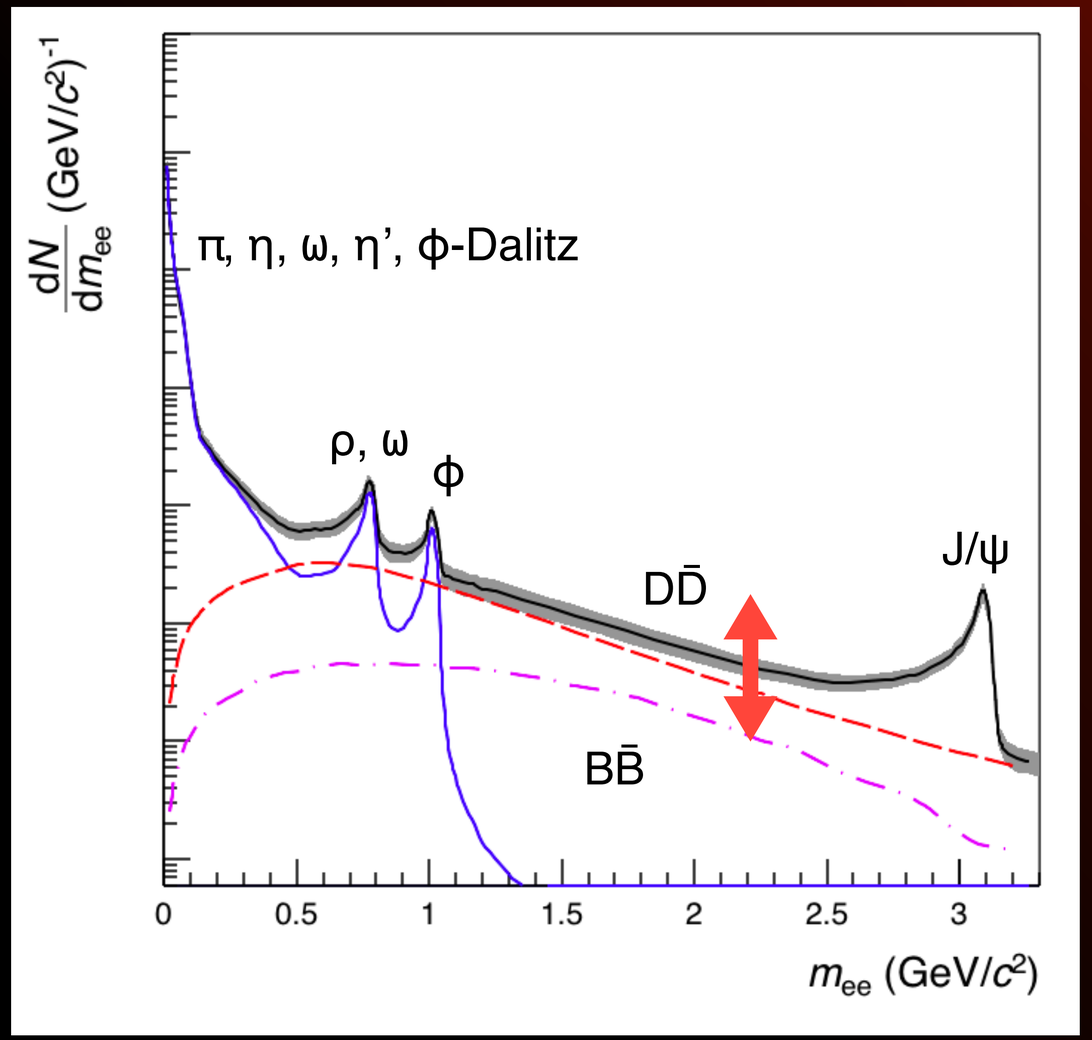


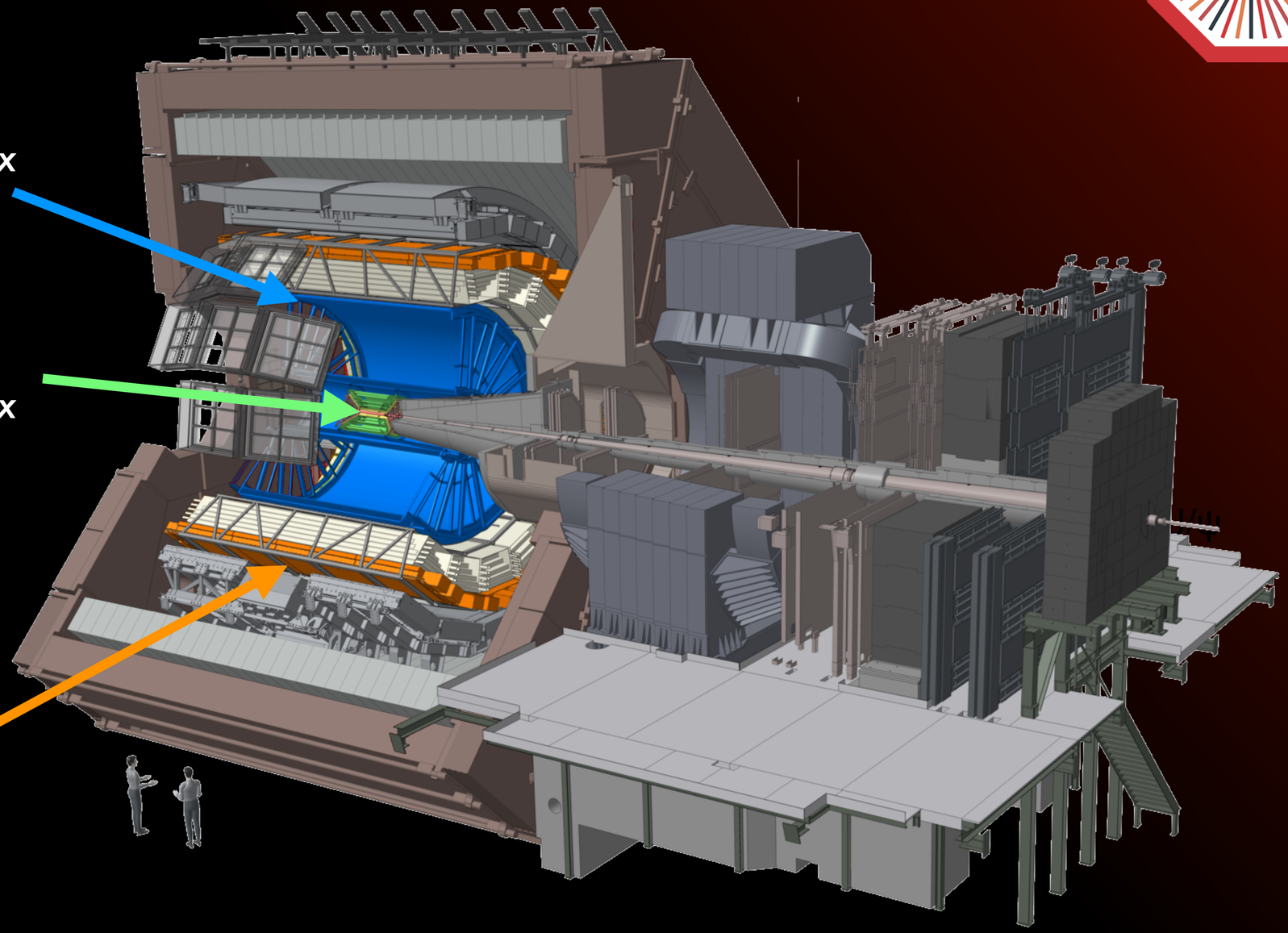
The ALICE Detector

Time Projection Chamber
- Particle identification via d*E*/d*x*
- Tracking

Inner Tracking System
- Particle identification via d*E*/d*x*
- Tracking
- Vertex determination

V0
- Centrality estimation
- Trigger

Time Of Flight
- Particle identification



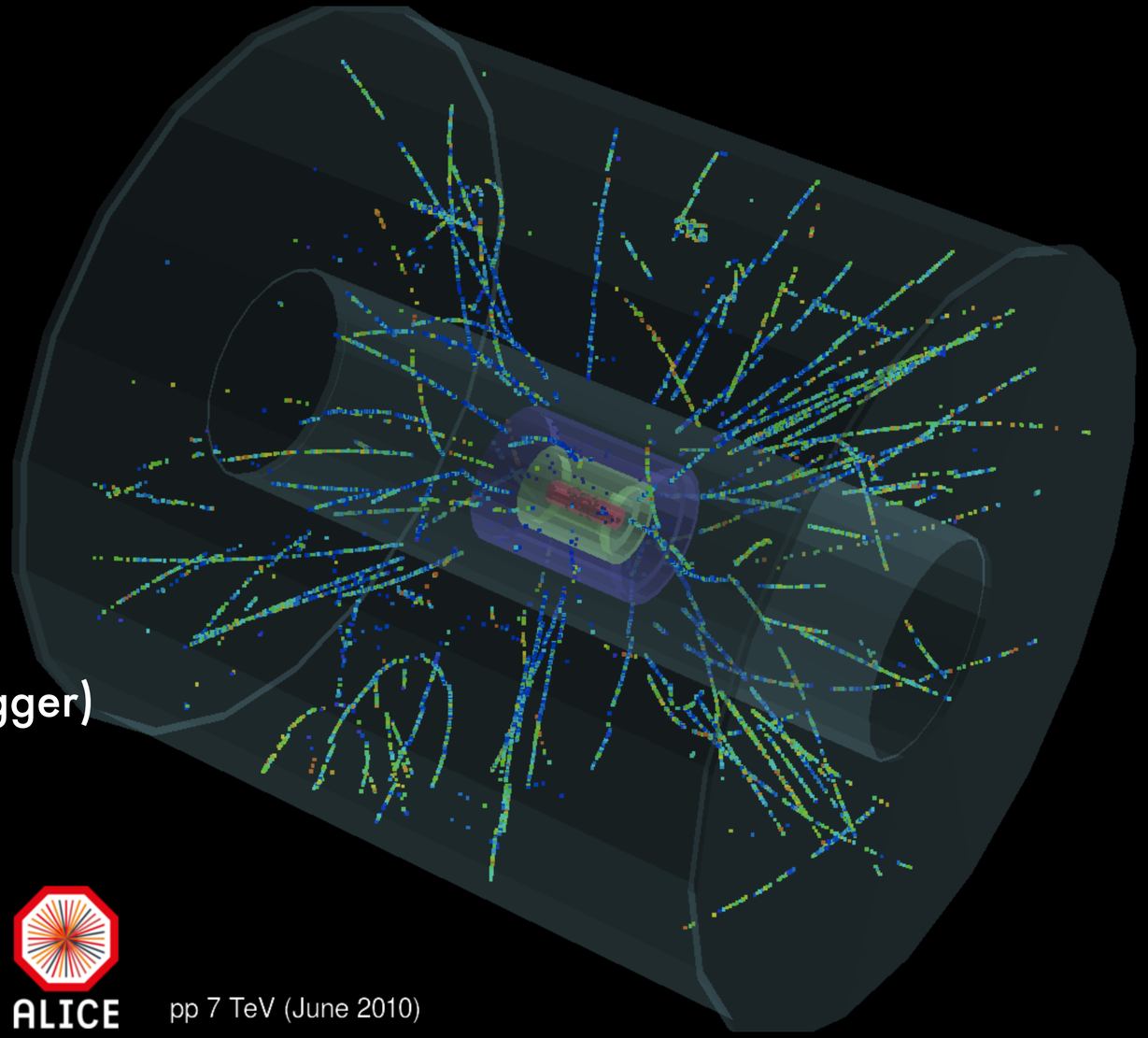
pp Collision Data

Run 1

- $\sqrt{s}$ = 7 TeV (minimum bias trigger)
  370M events, JHEP 1809 (2018) 064

Run 2

- $\sqrt{s}$ = 13 TeV (minimum bias and high multiplicity trigger)
  450M events, PLB 788 (2019) 505
- $\sqrt{s}$ = 5 TeV (minimum bias trigger)
  880M events, PRC 102 (2020) 5



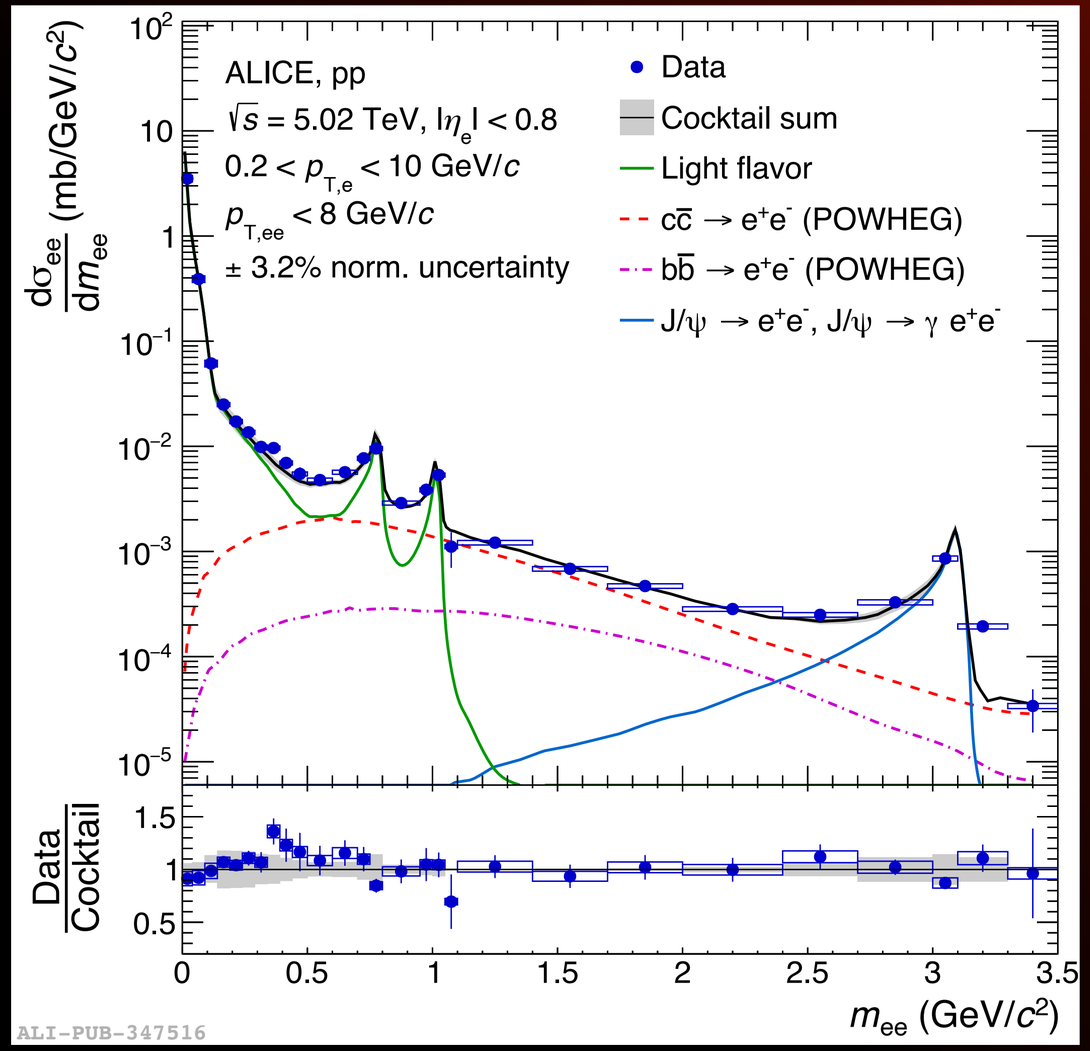
ALICE

pp 7 TeV (June 2010)

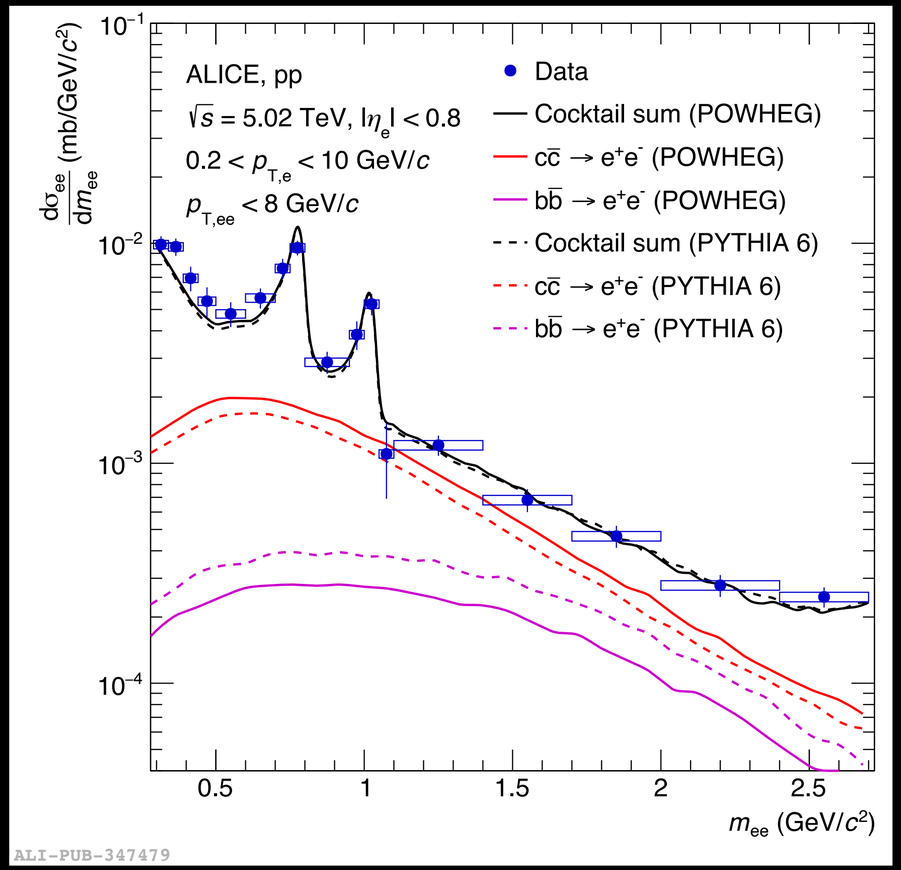
The Dielectron m_{ee} Spectrum

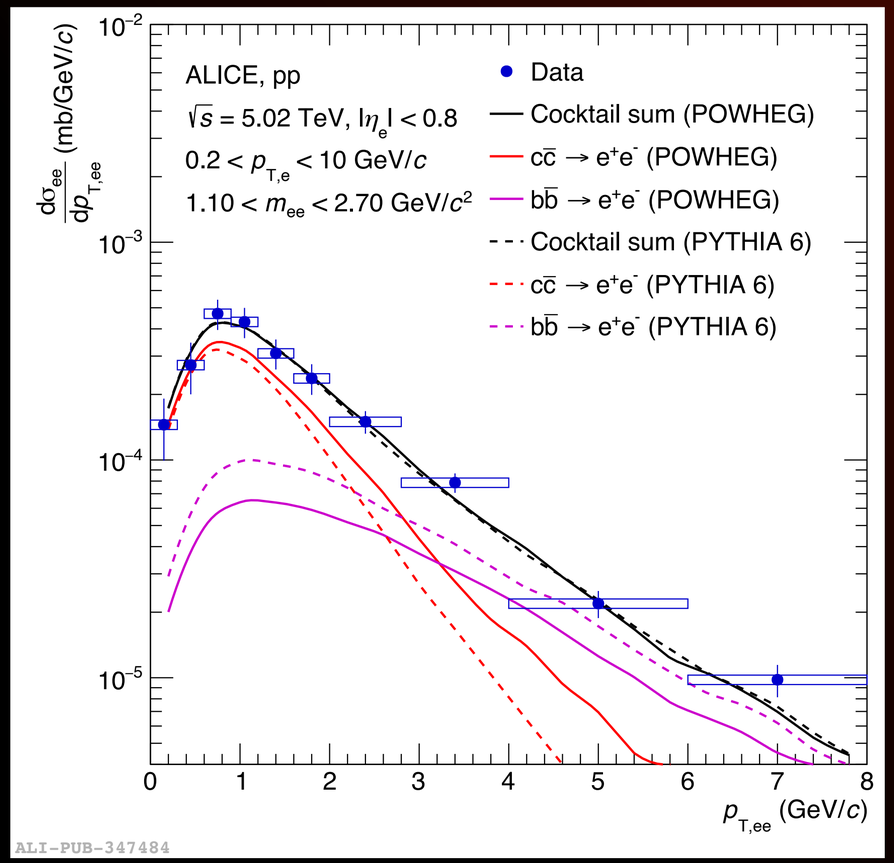
Dielectron production cross section as a function of m_{ee} measured in pp collisions at $\sqrt{s}$ = 5.02 TeV

- Measurement is compared to expection from known hadronic sources (hadronic cocktail)
  - Light-flavour sources and J/ψ from parametrisation of independent measurements and particle ratios from PYTHIA
  - Heavy-flavour from two dimensional fit (m_{ee}/$p_{T,ee}$) in the intermediate mass region



Heavy-Flavour in pp at 5 TeV



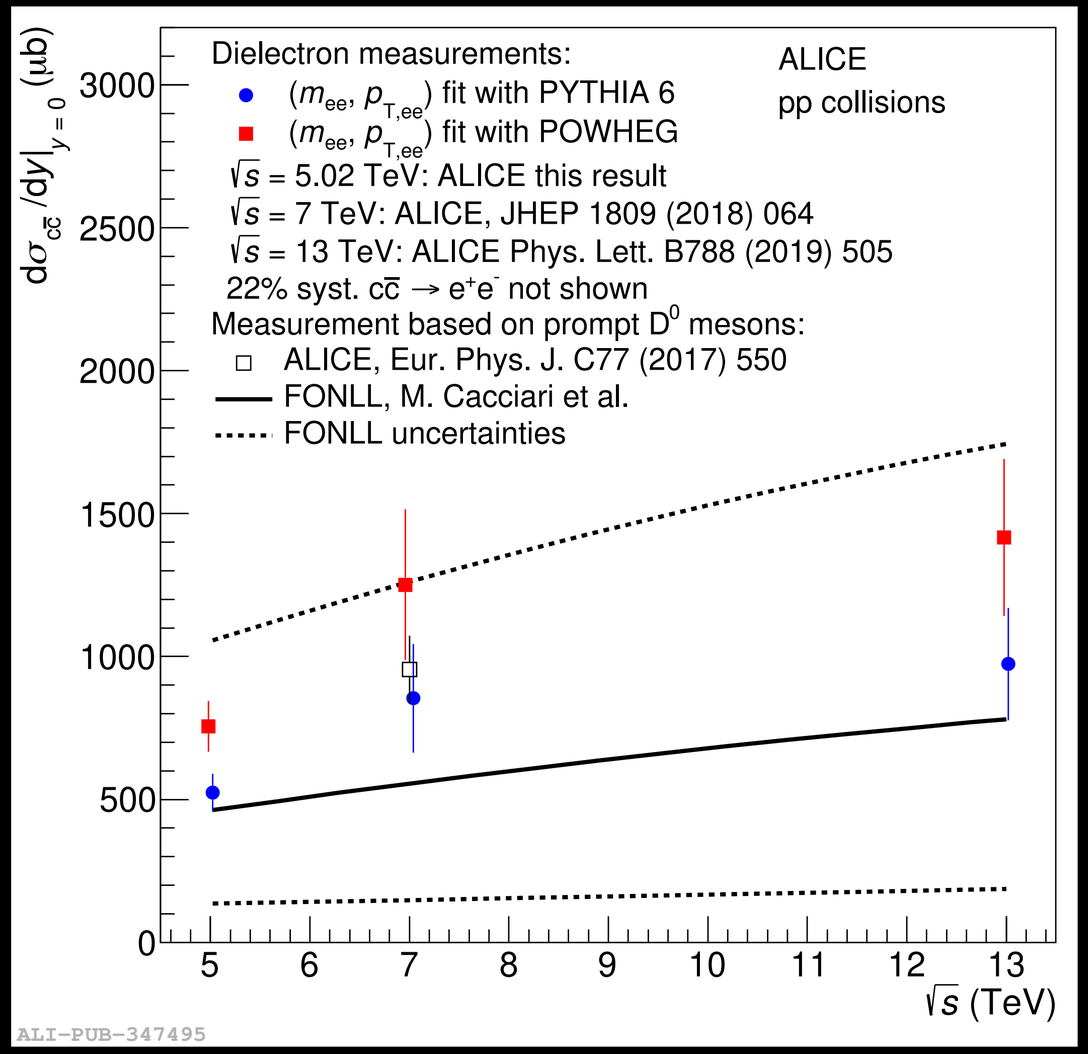


Distinct shape of charm and beauty as a function of m_{ee} and $p_{T,ee}$ used to fit data in $1.1 < m_{ee} < 2.7$ GeV/c^2

Extrapolate to full phase space based on model to get cross section

Model dependence of beauty smaller than charm, but both are correlated in the fit

Charm production in pp



Similar analysis performed in pp collisions at 7 and 13 TeV

- Model dependence observed at all energies
- Consistent with independent measurements
- FONLL describes $\sqrt{s}$ dependence within large model uncertainies

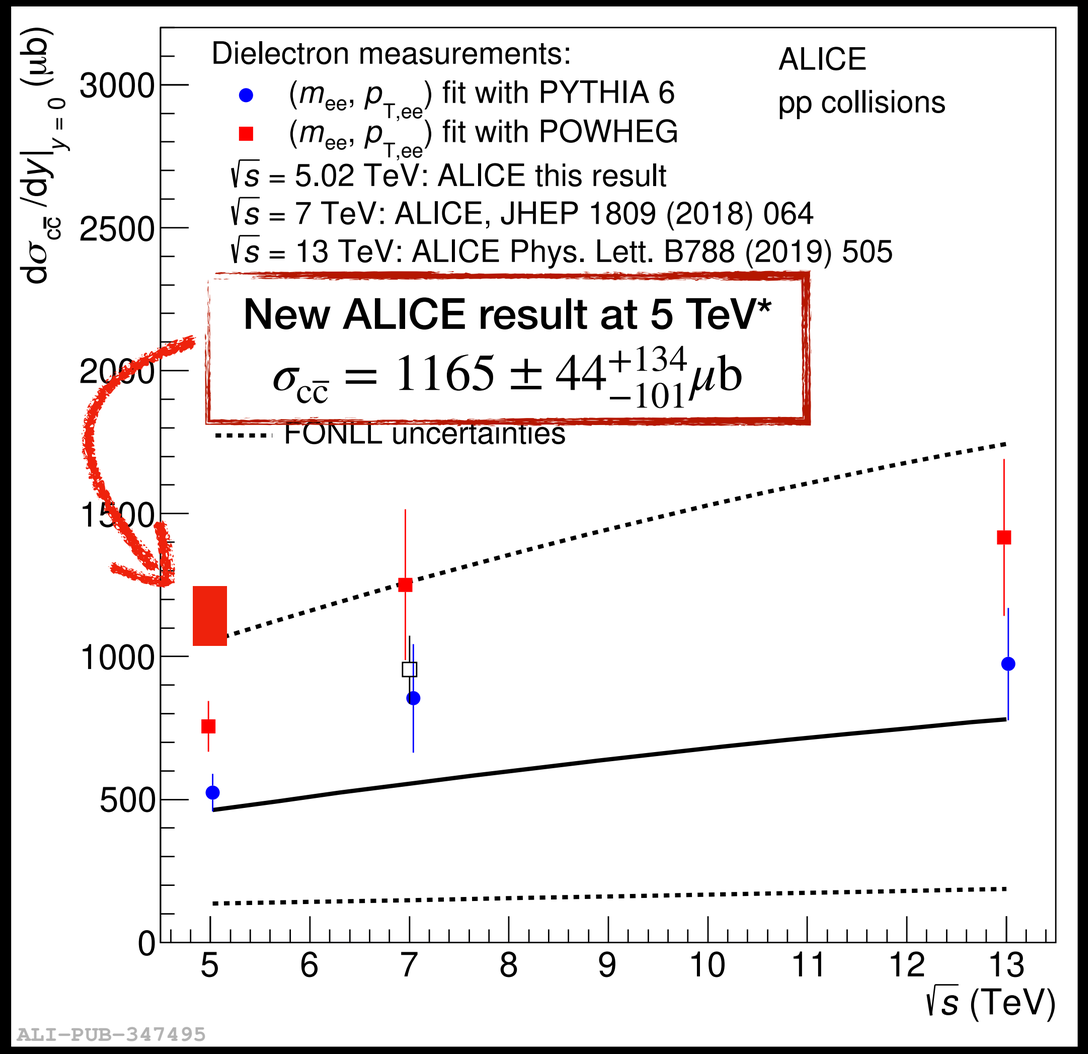
Differences in models are the p_T spectra of the electrons (quarks) reflected in the $p_{T,ee}$

Additional difference in η distributions (extrapolation)

- Sensitivity of dielectron measurement to implementation of charm quark production mechanisms

Charm production in pp

*arXiv: 2105.06335, Jinjoo Seo, Tue 19:20



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What changed?

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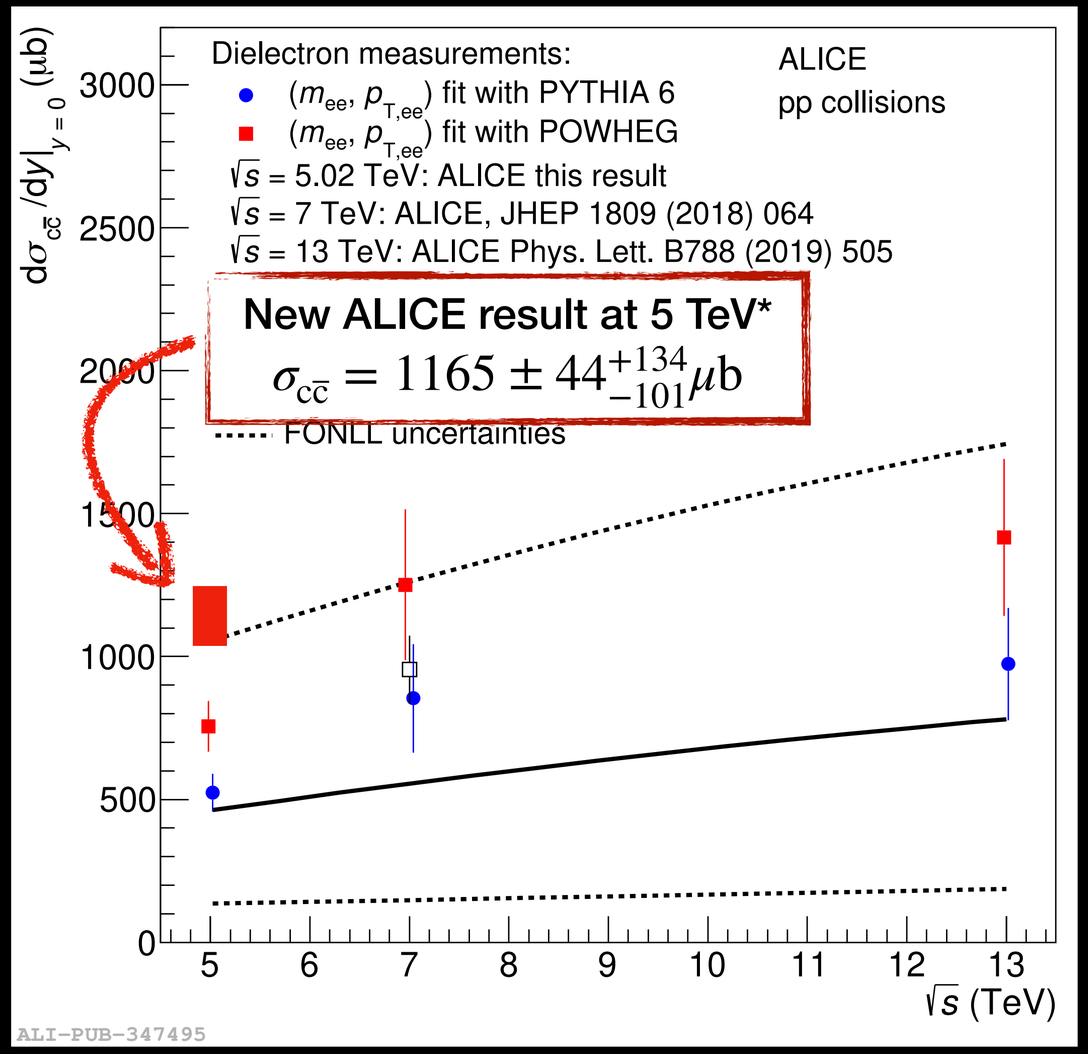


Dielectron and previous measurement based on D^0 used fragmentation functions (FF) from LEP measurements.

New results from ALICE show a much higher contribution from charmed baryons

- Λ_c increased by factor 3.3, Ξc included
- Baryons have rather small branching ratios into electrons compared to the mesons:
  $\Lambda_c \rightarrow e$ = (3.95±0.35)%
  $D^+ \rightarrow e$ = (16.07±0.30)%

Including these new FF in estimate based on D^0 measurement leads to 40% higher cross section

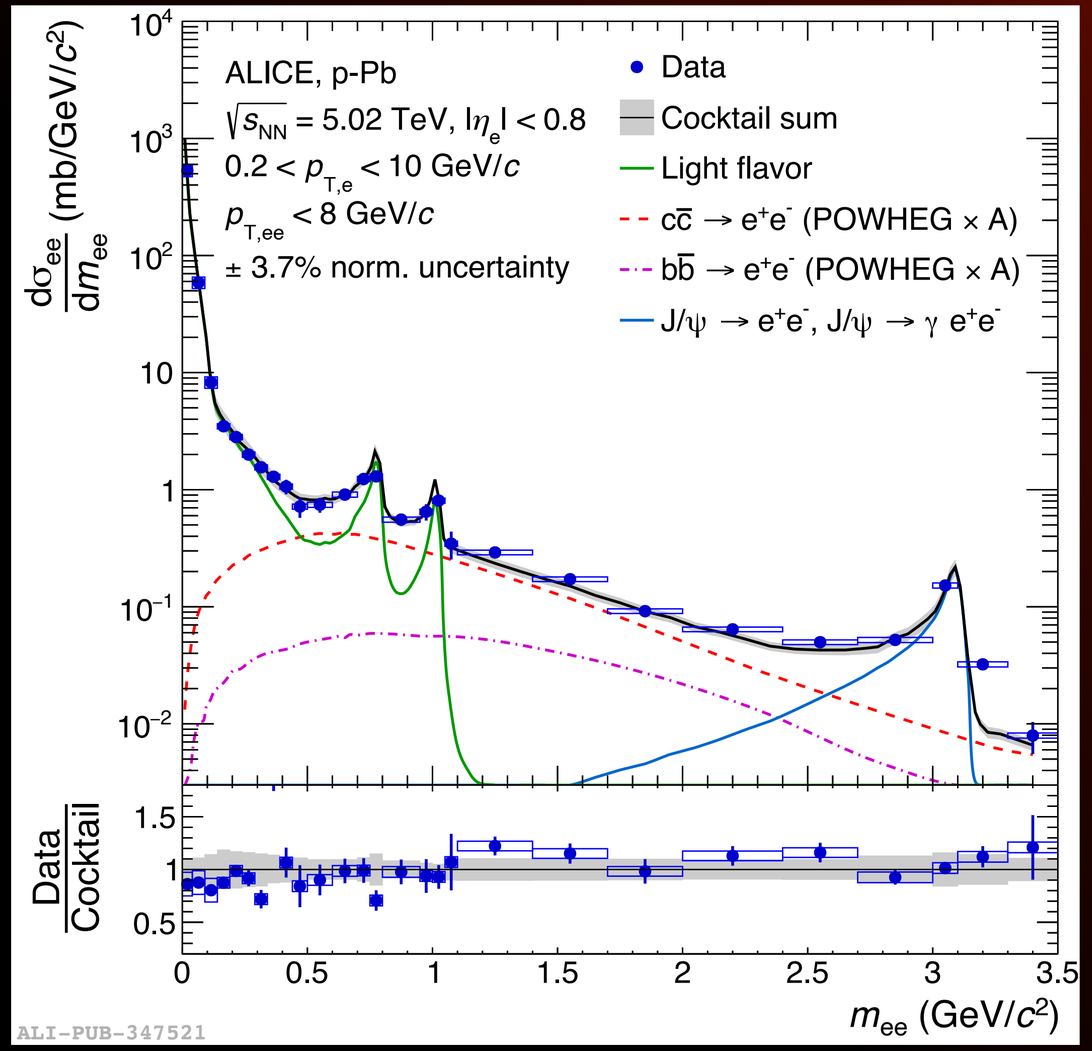
Will also push up dielectron based results by factor 30-40%

Dielectron Production in pPb

Dielectron production cross section as a function of m_{ee} in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

- HF from binary NN collision scaling of cross section measured in pp collisions (can neglect FF here)
- Overall good agreement of hadronic cocktail with data
- Systematic uncertainties on cocktail limit interpretation of data

Compare data to data to circumvent dependence on cocktail uncertainties

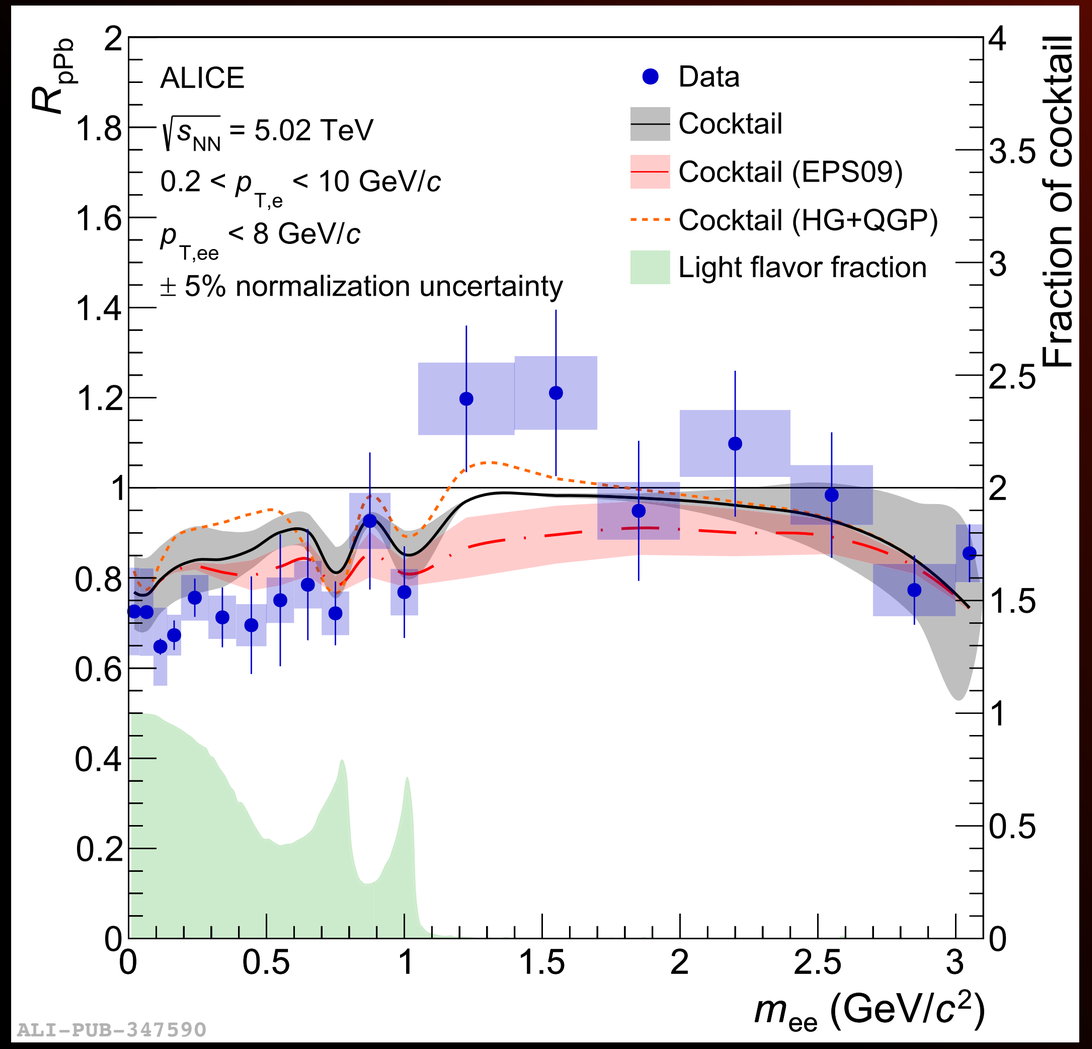


Nuclear Modification Factor

$$R_{\mathrm{pPb}} = \frac{1}{A}\frac{\mathrm{d}\sigma_{\mathrm{ee}}^{\mathrm{pPb}}/\mathrm{d}m_{\mathrm{ee}}}{\mathrm{d}\sigma_{\mathrm{ee}}^{\mathrm{pp}}/\mathrm{d}m_{\mathrm{ee}}}$$

Dielectron nuclear modification factor as a function of m_{ee} at $\sqrt{s_{NN}}$ = 5.02 TeV compared to cocktails:

1. Assuming binary NN collison scaling of the HF contributions (vacuum baseline)
2. Including modifications of charm production via CNM effects based on EPS09 nPDF
3. Including additional dielectrons from hadronic and partonic phase based on a fireball model



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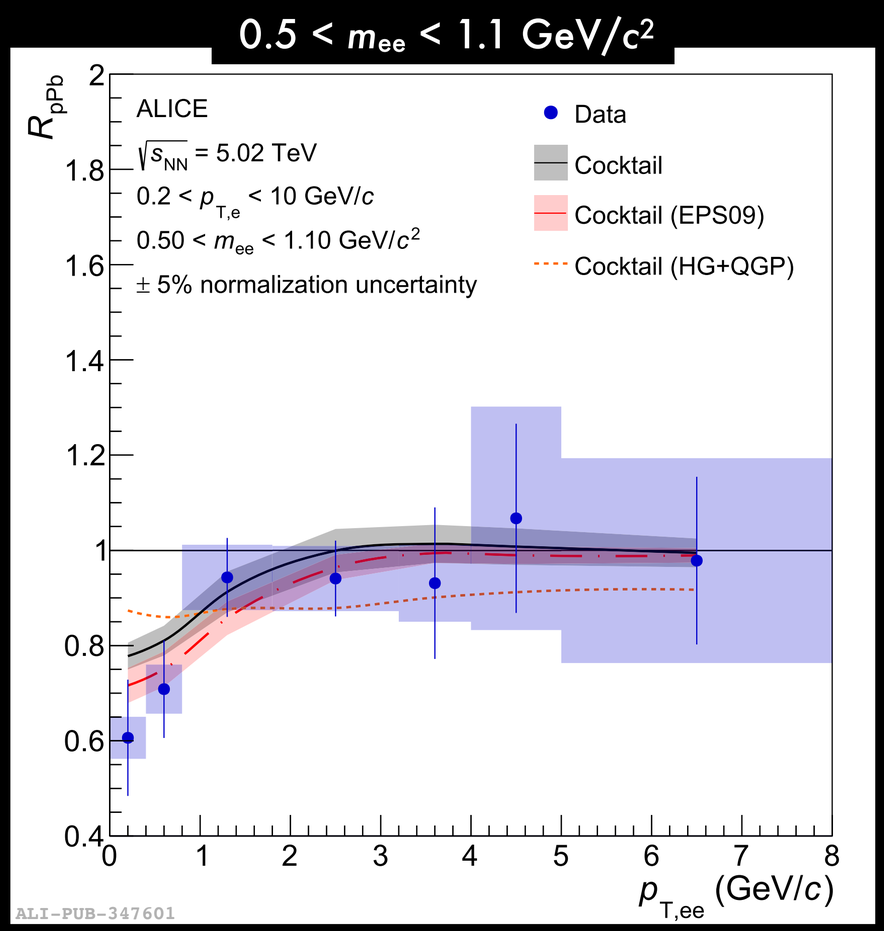
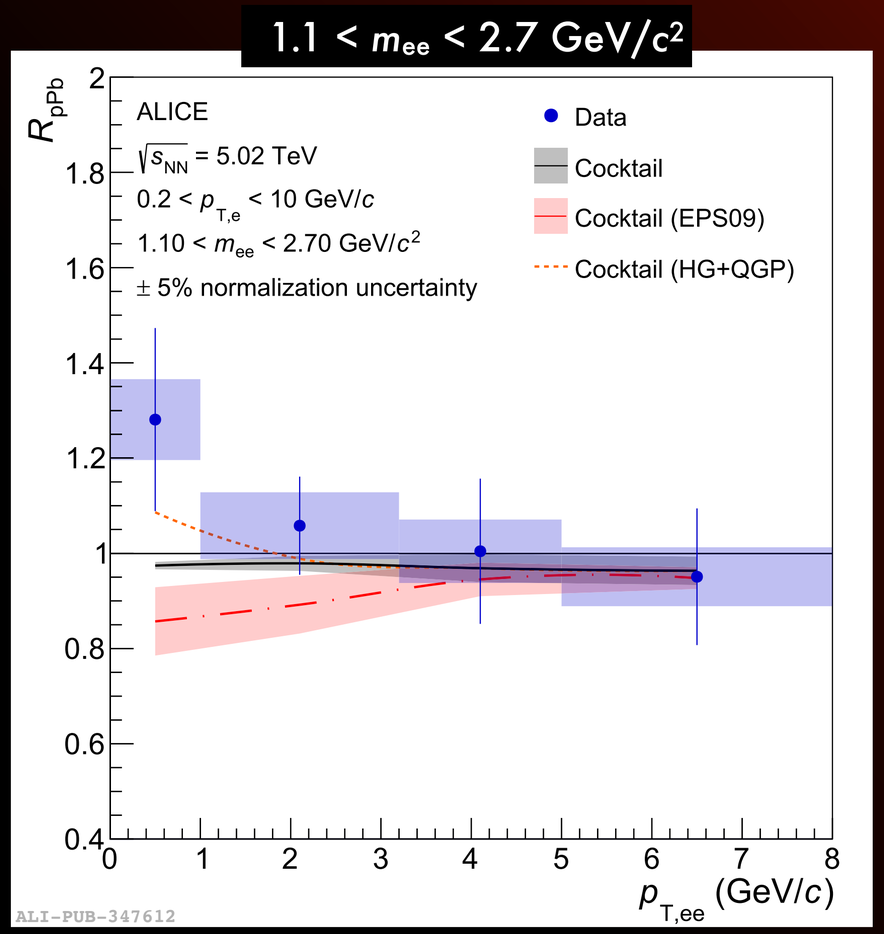
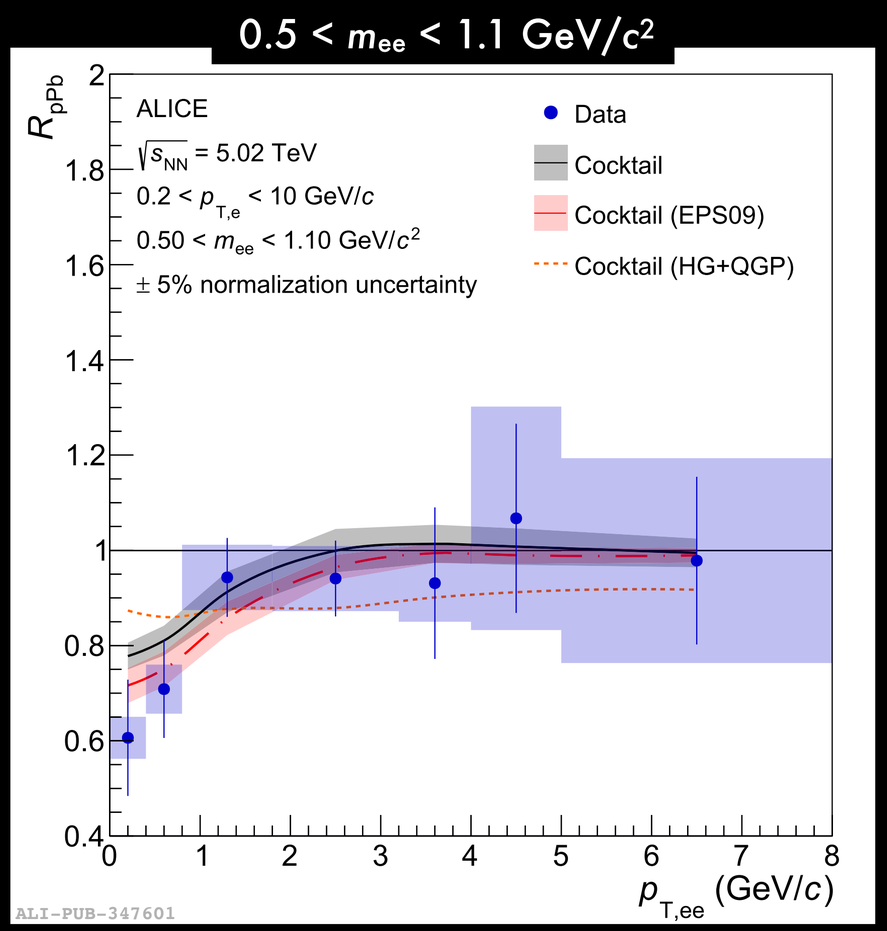


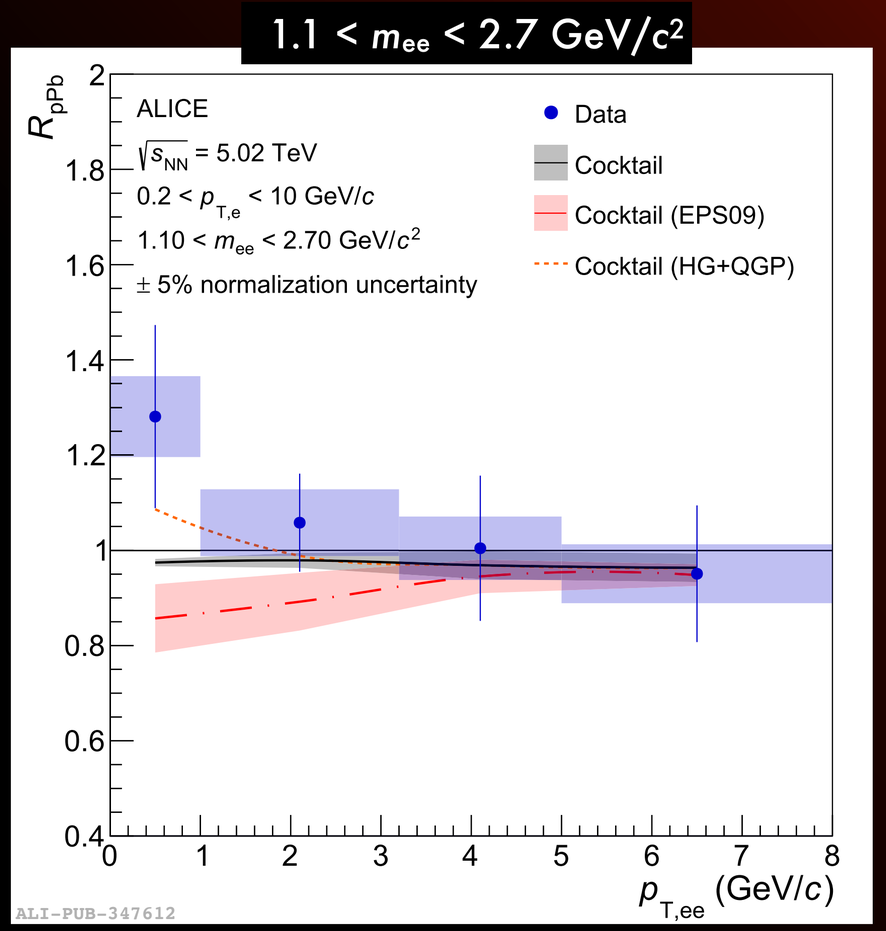
Above 1 GeV/c data described by binary NN collision scaling
Deviations can be described by vacuum cocktail



Data consistent with unity over whole $p_{T,ee}$ range within uncertainties

Nuclear Modification Factor





Crucial to separate prompt and non-prompt contributions
→ Use Distance-of-Closest-Approach of tracks to vertex (analysis ongoing)

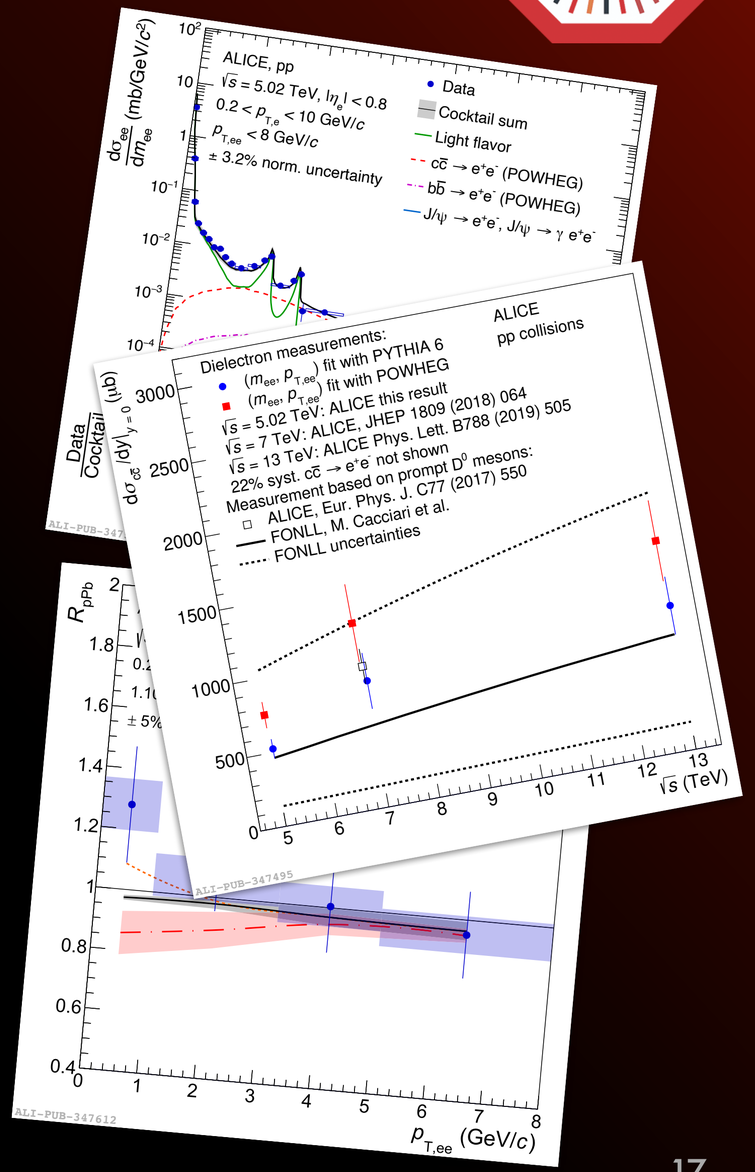
Summary

ALICE is actively studying charm production with different techniques

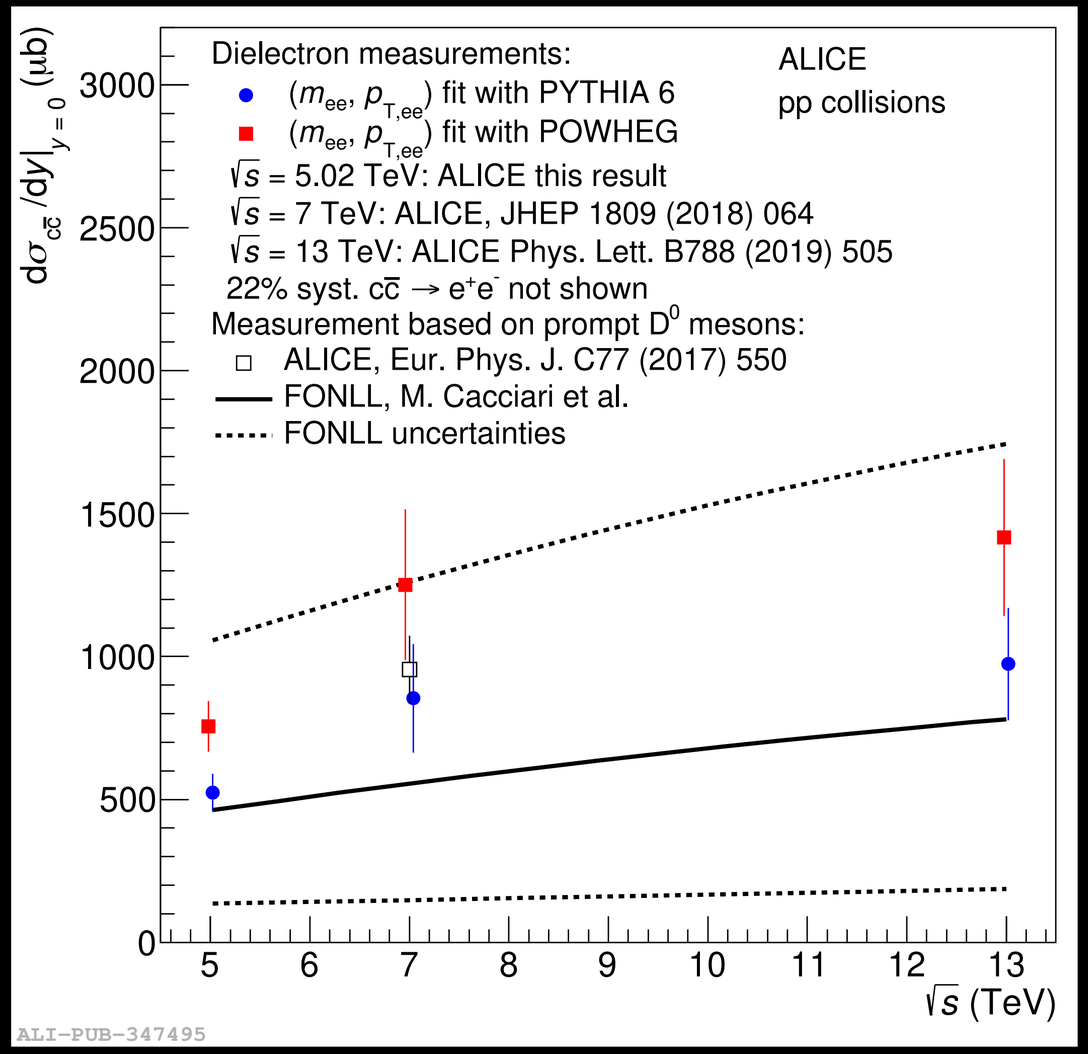
- Fully reconstructed charmed hadrons to extract fragmentation functions and production cross section
  arXiv: 2105.06335
- Electron-positron pairs from the semi-leptonic decay of the heavy flavour hadrons show sensitivity to the implementation of the quark production mechanisms in event generators
  JHEP 1809 (2018) 064, PLB 788 (2019) 505, PRC 102 (2020) 5

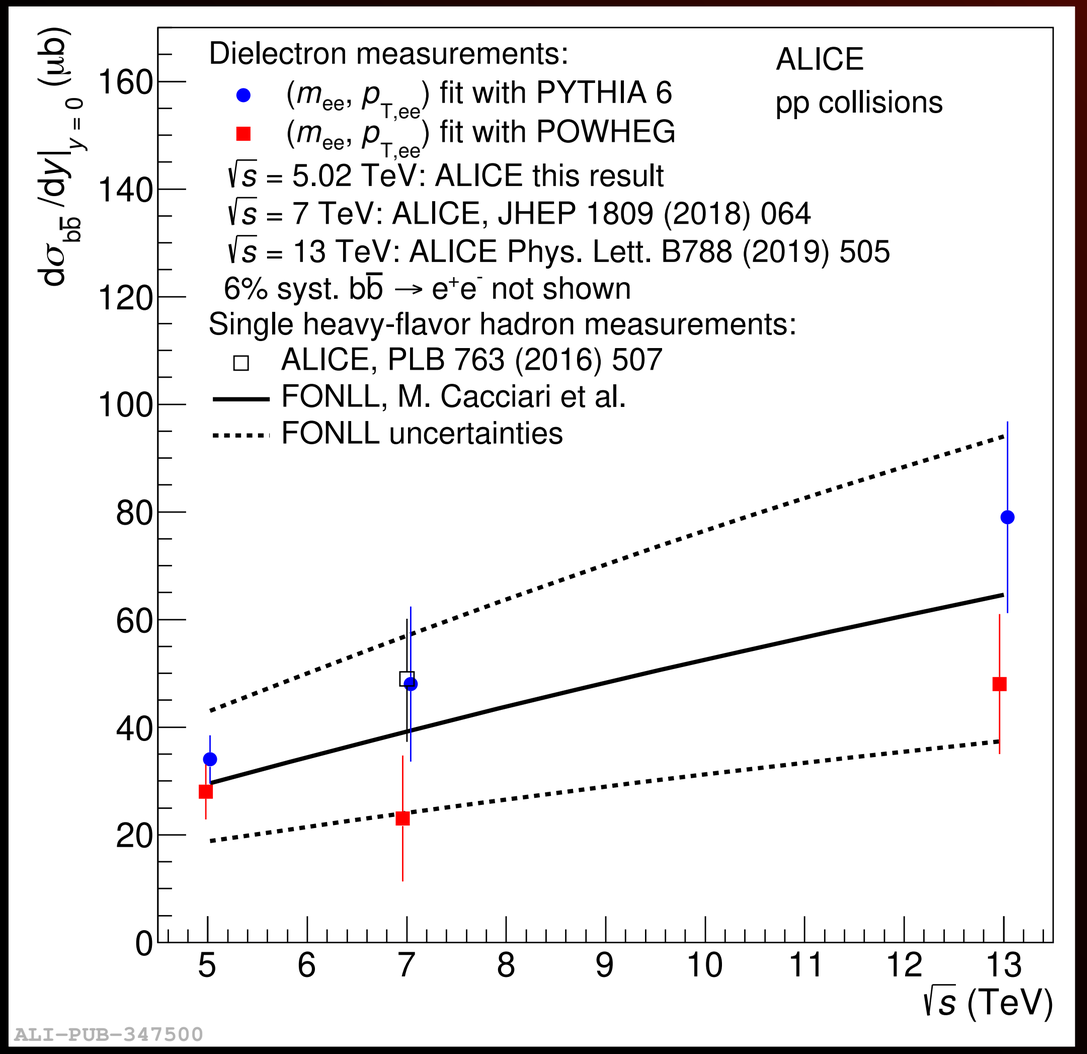
Separation of charm contribution and prompt dielectrons crucial for further constraints on spectrum modifications (shadowing, thermal source)

In LHC Run 3 we expect a factor 100 more data from upgraded Time Projection Chamber read-out system and factor 3-6 better prompt/non-prompt separation due to new Inner Tracking System



Backup


Dielectron measurements:
$(m_{ee}, p_{T,ee})$ fit with PYTHIA 6
$(m_{ee}, p_{T,ee})$ fit with POWHEG
$\sqrt{s}$ = 5.02 TeV: ALICE this result
$\sqrt{s}$ = 7 TeV: ALICE, JHEP 1809 (2018) 064
$\sqrt{s}$ = 13 TeV: ALICE Phys. Lett. B788 (2019) 505
22% syst. $c\bar{c} \rightarrow e^+e^-$ not shown
Measurement based on prompt D^0 mesons:
ALICE, Eur. Phys. J. C77 (2017) 550
FONLL, M. Cacciari et al.
FONLL uncertainties
ALICE
pp collisions
$d\sigma_{c\bar{c}}/dy|_{y=0}$ (μb)
$\sqrt{s}$ (TeV)
ALI-PUB-347495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$\sqrt{s}$ = 7 TeV: ALICE, JHEP 1809 (2018) 064
$\sqrt{s}$ = 13 TeV: ALICE Phys. Lett. B788 (2019) 505
6% syst. $b\bar{b} \rightarrow e^+e^-$ not shown
Single heavy-flavor hadron measurements:
ALICE, PLB 763 (2016) 507
FONLL, M. Cacciari et al.
FONLL uncertainties
ALICE
pp collisions
$d\sigma_{b\bar{b}}/dy|_{y=0}$ (μb)
$\sqrt{s}$ (TeV)
ALI-PUB-347500

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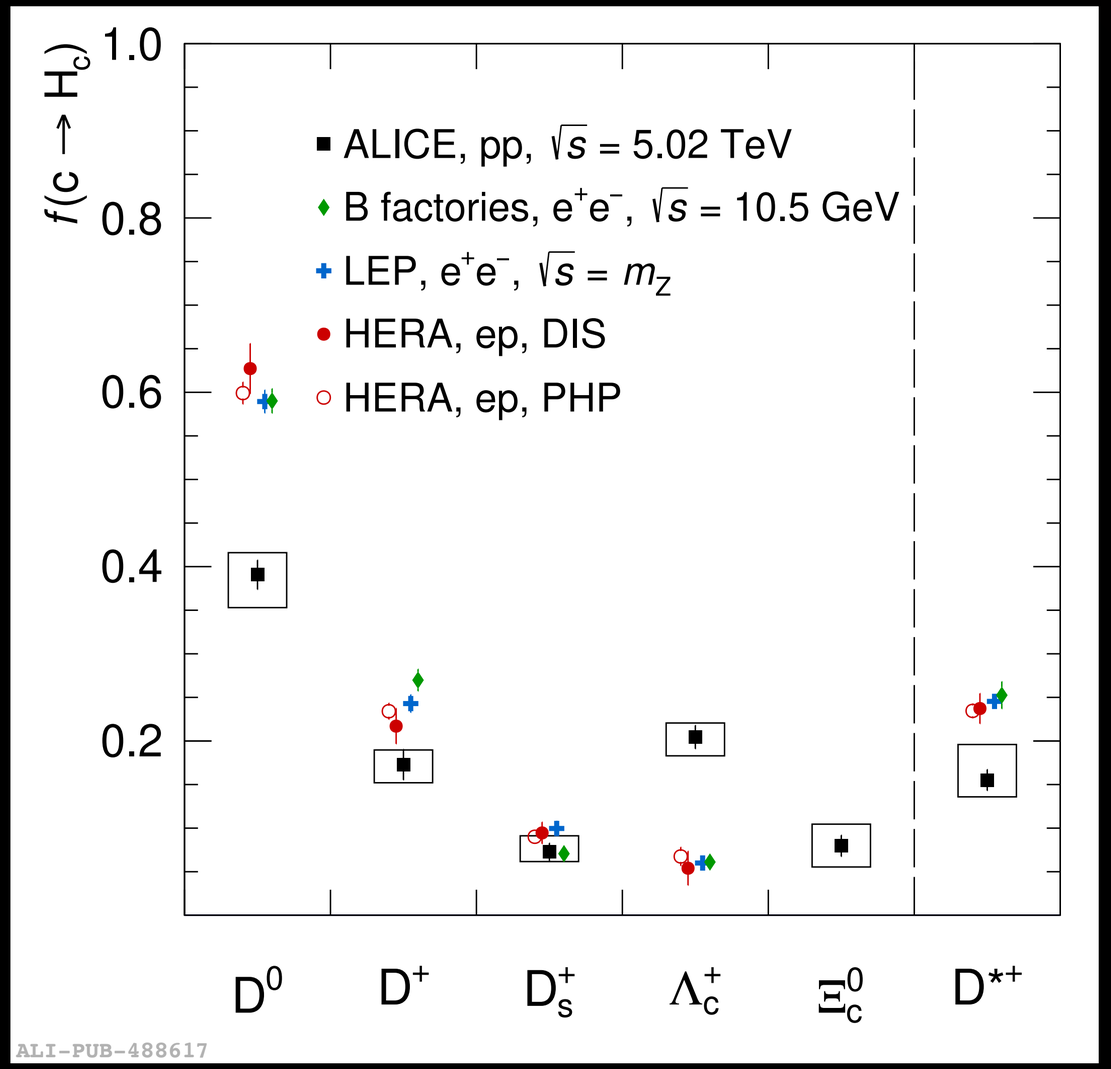

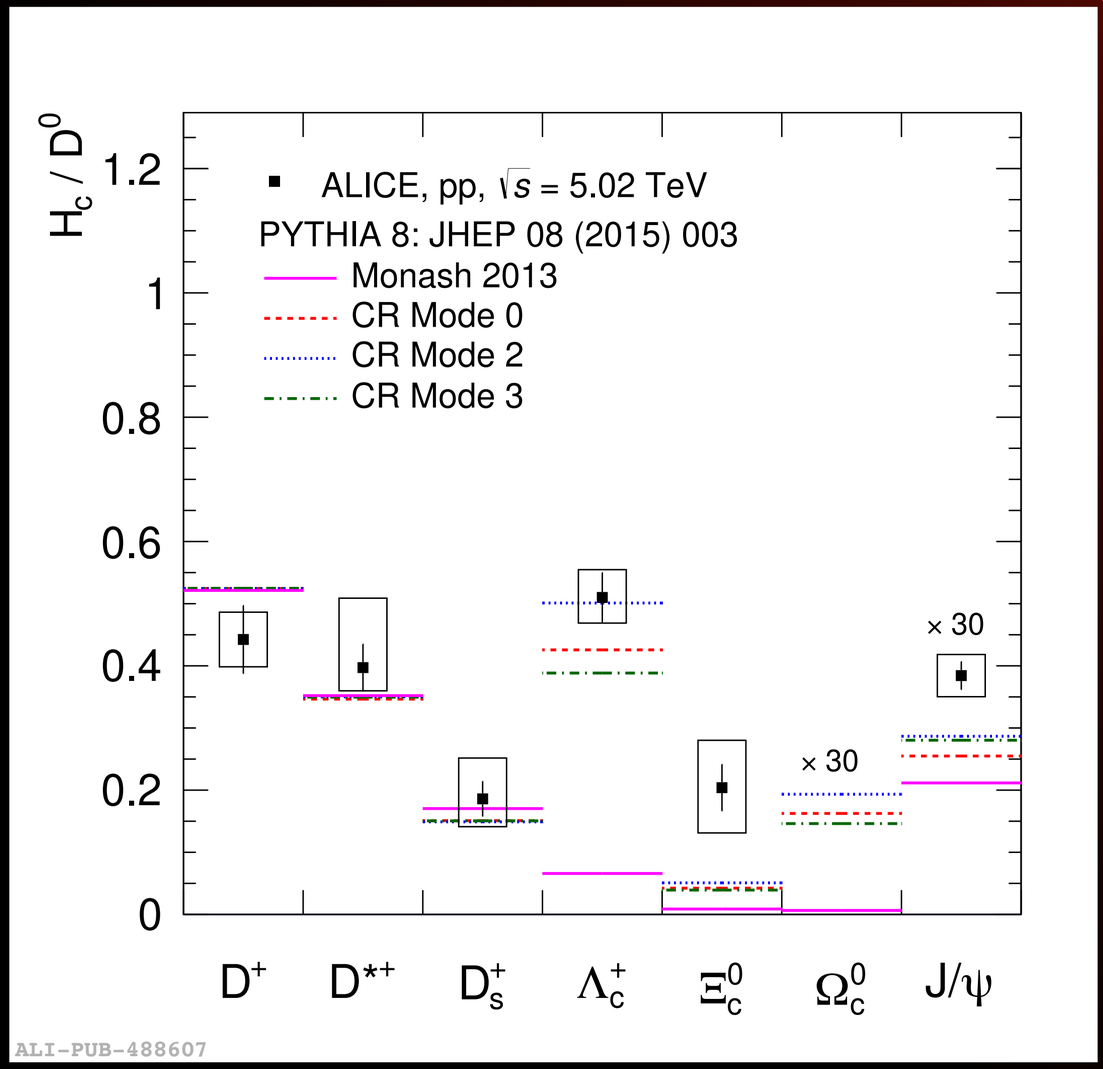

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